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The Fate of Nitrogen during Parent Body Partial Melting and Accretion of the Inner Solar System Bodies at Highly Reducing Conditions

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Evolution of nitrogen (N), a life-essential volatile element, in highly reduced magmatic systems is key for the origin of N on rocky planets formed via accretion of reduced chondritic parent body materials, planetesimals, and embryos that underwent partial or complete differentiation. However, the storage capacity of N in phases relevant for reduced silicate systems undergoing thermal processing is poorly known. To investigate the stability of N-bearing phases in partially molten silicate-rich systems as well as solubility of nitrogen in silicate melts and minerals, we performed laboratory experiments on a 80:20 synthetic basalt-Si_3N_4 mixture at 1.5-3.0 GPa and 1300-1600 °C in graphite capsules with oxygen fugacity ranging from IW– 5.9 to IW – 8.4. All experiments yielded silicate melt + nierite + Fe-rich alloy melt + N-rich vapor ± sinoite ± cpx. Sinoite was restricted to above while cpx was restricted below 1400-1500 °C. Nitrogen solubility and Nitrogen Concentration at Silicon-Nitride Saturation (NCNS) in silicate melts increases with increasing pressure and temperature and ranges between 3.6 and 9.5 wt %. Using our high pressure N solubility data and similar data at ambient and lower pressures, we derived a new N solubility model in silicate melts. Solubility of nitrogen in cpx was between 1.51 and 2.05 wt% and resulted in cpx/silicate melt partition coefficients for nitrogen, $D_N^{cpx\text{-}melt}$ of ~0.4 to ~0.2. These $D_N^{cpx\text{-}melt}$ are distinctly higher than that previously estimated at more oxidizing conditions, suggesting N maybe less incompatible during thermal processing of rocky reservoirs at extremely reducing conditions. Partition coefficient of N between Fe-rich alloy melt and cpx was found to be between 1.6 and 2.1. The application of our N solubility data and model suggests that mobilization of N from the deeper, partially molten reservoir to shallower reservoirs is possible in reduced planetesimals and internally differentiated meteorite parent bodies. Similarly, enrichment of N in the planetary atmosphere may be a result of gradually more oxidizing accreting materials, which would lead to N being more incompatible during internal and external magma ocean processing of rocky bodies.